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ScienceDirect

Procedia
Social and Behavioral Sciences

Procedia - Social and Behavioral Sciences 90 (2013) 431 – 440

6th International Conference on University Learning and Teaching (InCULT 2012)

# Parallel Circuit Conceptual Understanding Test (PCCUT)

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**Abstract**

The concern of academicians regarding the understanding achieved upon instruction of electricity has given rise to the development of various instruments. Even though there are many studies on misconceptions in electricity, very few have used diagnostic instruments in identifying the students' strength and weaknesses including profiling them according to their ability. The aim of this paper is to investigate the validity of the instrument, *Parallel Resistive Conceptual Understanding Test (PCCUT)* using Rasch Analysis in measuring the conceptual understanding of engineering students on the topic of parallel resistors, including exploring the possibility of profiling them according to their understanding. The methods used are by purposive sampling on 102 students, consisting of 55% (56) majoring in Electrical Engineering, 27% (28) in Mechanical Engineering and 18% (18) in Civil Engineering. The instrument focused on the six main domains which are "the meaning of parallel", practical knowledge of "current", "voltage", "resistance", "circuit connection" and "mental model". Data collected were analyzed using WINSTEPS version 3.71.0.1. The result shows that the valid instrument has 'excellent' item reliability of 0.97 logit and 'good' item separation of +5.37 logit (item strata of 7.49).


Selection and/or peer-review under responsibility of the Faculty of Education, University Technology MARA, Malaysia.

*Keywords*: diagnostic instrument; parallel resistors; Rasch analysis.

## 1. Introduction

The concern of academicians regarding the amount of understanding that has been achieved upon instruction of specific area has given rise to the development of various diagnostic instruments. This academic assessment is regarded as one important tool to measure the students' abilities upon instruction. Jackson, Draugalis, Slack & Zachry (2002) stressed on the fact that assessment is one method of gaining information regarding the students' understanding in a particular field. Students' performance and standards of mastery are

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Selection and/or peer-review under responsibility of the Faculty of Education, University Technology MARA, Malaysia.
doi:10.1016/j.sbspro.2013.07.112

the focus of assessments. By conducting assessments on the students enables the instructors in accessing the areas of strengths and weaknesses. Hence, students are able to be profiled according to their understanding.

## 2. Background study

In the field of science, diagnostic instruments have been widely used to identify students' ideas and misconceptions (Borges, 1999; Liegeois & Mullet, 2002; Canpolat, 2006; Treagust, 2006; Bradley, Cunningham, & Sampson, 2007). As for the area of Physics, there are a few instruments which can assess the students' difficulties on the topic of electricity in general such as *DIRECT- Determining and Interpreting Resistive Electric Circuit Concept Test* (Engelhardt & Beichner, 2004) and *PECA - Path of Electric Circuit Assessment* (Henry & Jabot, 2004). The author believes that the instrument designed for this purpose will be very useful in investigating other factors affecting the students' conceptual understanding on the area of electricity.

Despite the fact that there is an abundance of studies on misconceptions in electricity, there are very few studies that have used diagnostic instruments in identifying the students according to their ability or level of understanding. Majority of the work done were to investigate and identify the students' learning difficulties. A well planned, reliable and valid diagnostic instrument can provide information relating to the area of strength and weaknesses of the students including the misconceptions that they may have on a particular topic. This then, could be used as the performance indicator of the students based on their understanding of that subject matter.

## 3. Aim of research

The aim of this research is to investigate on the validity and reliability of the Parallel Circuit Conceptual Understanding Test (PCCUT) in assessing the engineering students' conceptual understanding on parallel resistors. It also aims to explore the possibility of the instrument to profile the students according to their basic understanding.

## 4. Methodology

The questionnaire of 34 items (PCCUT) were administered to the engineering students and the data was collected. The analysis of the data was done using Rasch Analysis Software (WINSTEPS 3.71.0.1). It serves as a tool in identifying the common problems faced by the students on the area of parallel resistors. Consequently, an intervention program can be conceived to assist the students in their area of difficulties and hence enable them to be better engineering student.

### *4.1 Respondents*

The samples for this research were purposive where a selected group of engineering students studying in a local Malaysian university was identified. A random group of 102 students from 325 students of mixed ability from different engineering background were chosen. There are 55% (56) of students in Electrical Engineering, 27% (28) in Mechanical Engineering and 18% (18) in Civil Engineering.

### *4.2 The instrument*

PCCUT was divided into six (6) sections which represent the problematic areas encountered by most engineering students. The six sections are:

- Section 1 – Meaning of the parallel
- Section 2- Practical Knowledge of Current
- Section 3 – Practical Knowledge of voltage in parallel circuit

- Section 4- Practical Knowledge of Resistance
- Section 5- Practical Knowledge of circuit connection: parallel and series
- Section 6- Mental Model

## 5. An overview of Rasch Measurement Model

It is common practice for academicians to assess students' ability on an examination or test by performing calculations based on their correct responses and hence producing total raw scores (Saidfudin, Azrilah, Rodzo'an, Omar, Zaharim, & Basri, 2010). A student who obtained 90% in an examination ranks higher than those who achieved 70% thus indicating that these scores are of ordinal data. Data placed in ranking order are not linear but is of continuum in nature. They do not have equal intervals which is necessary for statistical analysis. Hence, it must be put to practice in reading the score of 90% as the odd of success being 90:10. This type of data which is the ratio data is more appropriate for measurement purposes (Stevens, 1946). Ratio data have a distinguishing feature which is the possession of a non-arbitrary zero value.

The Rasch Measurement Model is a formulation that stipulates the relationship between a person and an item based on a mutual latent trait. To be more precise, it is able to predict the likelihood of a person of a given capability to correctly respond to an item of a certain difficulty level. The probability of success depends on the difference between the ability of the person and the difficulty of the item, Bond & Fox (2007).

The Rasch Measurement Model is based on two fundamental theorems which say that:

- A person who is more capable has a greater likelihood of correctly answering all the items given.
- An easier item is more likely to be answered correctly by all persons.

In other words, the Rasch Model assumes that the item difficulty is the attribute that is influencing the person responses while the person ability is the attribute that is influencing the item difficulty estimates (Linacre, 1999).

Fit statistics by Rasch Analysis enable the researchers to see whether the data they are using is feasible; specifically higher ability students should be more likely to answer items of greater difficulty correctly than the lower ability students (Bradley, Cunningham & Sampson, 2007). It includes the outfit and infit (mean square and standardized values) of the persons and items. According to Green and Frantoum (2002), the term fit refers to "infit" (weighted by the distance between the person position and item difficulty) and "outfit" (an unweighted measure). If the data fit the Rasch model, then the expected values of the mean square and the standardized fit indices are 1.0 and 0.0 respectively. Often, outfit is more sensitive to extreme responses compared to the infit.

A misfit item means that the particular item is either too difficult or too easy for the respondent; or it could mean that the item is not really testing on the desired latent trait. There are means of checking for quality control in Rasch. In order to verify for fit and misfit items or persons, the following criteria must be satisfied:

- Point Measure Correlation: $0.32 < x < 0.8$
- Outfit Mean Square, $0.5 < y < 1.5$
- Outfit Z standard , $-2.0 < Z < +2.0$

## 6. Overall Findings

An appraisal of data fit to PCCUT was conducted as a mean of observing the extent that the students' responses to each item are consistent with the responses to other items on the assessment (Smith, 2005). A total data point of 3468 evolved from 102 respondents on the 34 items analyzed. It produces a Chi – square value of 3143.65 with 3333 degree of freedom (p= 0.9908) (Table 1). This means that the overall fit to the measurement is good. For this set of data, it can be seen that the mean infit and outfit for item mean square are 1.00 and 0.95 respectively; very much as the expected value of 1.00 (Linacre, 2011). Similarly, the mean infit and outfit person mean square are both at 1.00 and 0.95 respectively.

The mean Z standardized infit and outfit values are expected to be 0.0. As displayed in Table 1, the mean infit and outfit values for the item's Z-standard are 0.0 and -0.1 while the mean infit and outfit for the person's Z-standard are 0.0 and 0.1. Since the values for the mean square and the Z-standard are very much close to the expected values, therefore, it can be said that the data for the actual research does fit the Rasch model reasonably well and appropriate analysis conducted can reveal the outcome of this research.

Table 1. Summary Statistic for 102 students

| Summary Of 102 Measured Person | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 15.8 | 34.0 | -.20 | .45 | 1.00 | .0 | .95 | .1 |
| S.D. | 5.5 | .0 | 1.08 | .05 | .21 | 1.0 | .35 | .5 |
| Max. | 31.0 | 34.0 | 3.40 | .72 | 1.50 | 2.0 | 1.99 | 1.4 |
| Min. | 5.0 | 34.0 | -2.67 | .42 | .54 | -2.0 | .33 | -.8 |
| Real RMSE .47 | True SD .97 | | Separation 2.06 | | Person Reliability .81 | | | |
| Model RMSE .45 | True SD .98 | | Separation 2.17 | | Person Reliability .83 | | | |
| S.E. of Person Mean = .11 | | | | | | | | |
| Person RAW SCORE-TO-MEASURE CORRELATION = 1.00 | | | | | | | | |
| CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .82 | | | | | | | | |

| Summary Of 34 Measured Item | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 47.4 | 102.0 | .00 | .30 | 1.00 | .0 | .95 | -.1 |
| S.D. | 26.6 | .0 | 1.87 | .15 | .15 | 1.4 | .31 | 1.5 |
| Max. | 99.0 | 102.0 | 5.06 | 1.02 | 1.35 | 3.8 | 1.83 | 5.0 |
| Min. | 1.0 | 102.0 | -4.18 | .22 | .75 | -2.8 | .42 | -2.6 |
| Real RMSE .34 | True SD 1.84 | | Separation 5.37 | | Item Reliability .97 | | | |
| Model RMSE .33 | True SD 1.84 | | Separation 5.50 | | Item Reliability .97 | | | |
| S.E. OF Item MEAN = .33 | | | | | | | | |
| Item RAW SCORE-TO-MEASURE CORRELATION = -.97 | | | | | | | | |
| 3468 DATA POINTS. LOG-LIKELIHOOD CHI-SQUARE: 3143.65 with 3333 d.f. p=.9908 | | | | | | | | |

### *6.1 Reliability of the Instrument*

The process of reliability and validity is very much needed in appraising the quality and reconstructing of a diagnostic tool. According to Jackson, Draugalis, Slack & Zachry (2002), reliability is the consistency of an instrument in measuring what it is supposed to measure. As for this research, it is desirable to measure the conceptual understanding of the engineering students on the topic of resistive parallel circuits. In terms of the item reliability, the final version of PCCUT produced ‘excellent’ item reliability (Fisher, 2007) of +0.97 logit. It indicates that the probability of the difficulty levels of every item remaining exactly the same if the instrument were given to a different group of engineering students is high. Hence, the instrument holds an “excellent” position of not being dependent on the respondents.

The Person reliability is identified as ‘good’ at +0.81 logit by Fisher (2007). In addition, the Cronbach Alpha (KR-20) Person Raw score test reliability is slightly higher at +0.82 logit. With the reliability at +0.82 logit, if a similar set of instrument measuring the conceptual understanding of parallel resistors were given to these groups, then the likelihood of obtaining a similar pattern of ability in the person measure order table and the location of these engineering students on the person-item distribution map would be fairly similar (Azrilah, 2009).This is also an indication that this instrument is capable of categorizing and distinguishing the level of conceptual understanding of these engineering students.

### *6.2 Instrument Construct Validity*

Validity refers to the degree of success of measuring the specific construct (uni-dimensional) that the instrument is attempting to measure and in this case, it is the conceptual understanding of the engineering students on the topic of resistive parallel circuits. According to Smith (2005), the features of validity in terms of interpreting measures especially construct and content validity can be investigated within the Rasch measurement framework. In this study, the information related to the students' conceptual understanding of the resistive parallel circuit can be gathered from their responses given to the items dealing with all the topics related to electrical current, voltage, and resistance, ability to recognize and connect parallel circuits together with the ability to solve parallel resistors problems.

Content and item validity can be assessed by looking at the fit statistics (mean square infit and outfit values) and the spread of the item. It has been revealed earlier that the mean square and the Z-standardized values are very well within the expected values. Hence, the next overall statistics to consider is the separation of persons and items, which is the index of spread of the items' positions and the persons' positions. The items has a mean value, $\mu_{item}$ = +0.00 logit. It should be noted that the mean of the item is always arbitrarily set at 0.0 logit, to signify the 50:50 likelihood of obtaining a correct response from the students with ability comparable to the item's level of difficulty. So, for the present case, the item separation shows it to be at +5.37 logit. The number of item strata can be calculated out by:

$$\frac{4\ (\text{item separation index}) + 1}{3} = \frac{4(5.37) + 1}{3} = 7.49 \qquad (1)$$

This means that the items can be categorized into 7 levels of difficulties; the extremely difficult level, the very difficult level, the difficult level, the average level; the easy category, the very easy category and lastly the extremely easy category (Figure 1). According to Green and Frantom (2002), separation is affected by sample size. The larger the sample size, the tendency for the separation to increase and the error to decrease is higher.

The mean for the 102 engineering students is $\mu_{Person}$ = -0.20 logit. Since this value is negative, it can be confidently said that the 34 items in PCCUT were quite challenging for these respondents since the mean value for item, $\mu_{item}$ = +0.00 logit is slightly higher than $\mu_{Person}$ = -0.20 logit. Another indication to reflect on the level of difficulty of the tasks given in the instrument can be seen from the mean score of 15.8 (S.D. =5.5) out of 34 marks. This value is quite low, clearly stating that the items were rather challenging to these students. As for the person separation, it is displayed as +2.06 logit. Hence the number of person strata can be obtained from the following equation:

$$\begin{aligned} \text{Number of person strata} &= ((4\text{x person separation index}) + 1) / 3 \qquad (2)\\ &= ((4 \times 2.06) + 1)/3 \\ &= 3.08 \end{aligned}$$

This means that the students can be represented into three categories, the competent, the average and the less competent students (see Table 2 and Figure 1). The students whose positions are above the $\mu_{item}$ = +0.00 logit are considered as the competent students while those between $\mu_{item}$ = +0.00 logit and $\mu_{Person}$ = -0.20 logit are the average students. Lastly, those below the $\mu_{Person}$ = -0.20 logit are regarded as less competent. The term competent means that the students' basic conceptual understanding on the electricity concepts is good and they are capable of tackling all the tasks in every category. The competent students (N= 45) consist of 67% (N=30) Electrical Engineering students, 31% (N=14) Mechanical Engineering students and 2% (N=1) Civil Engineering students.

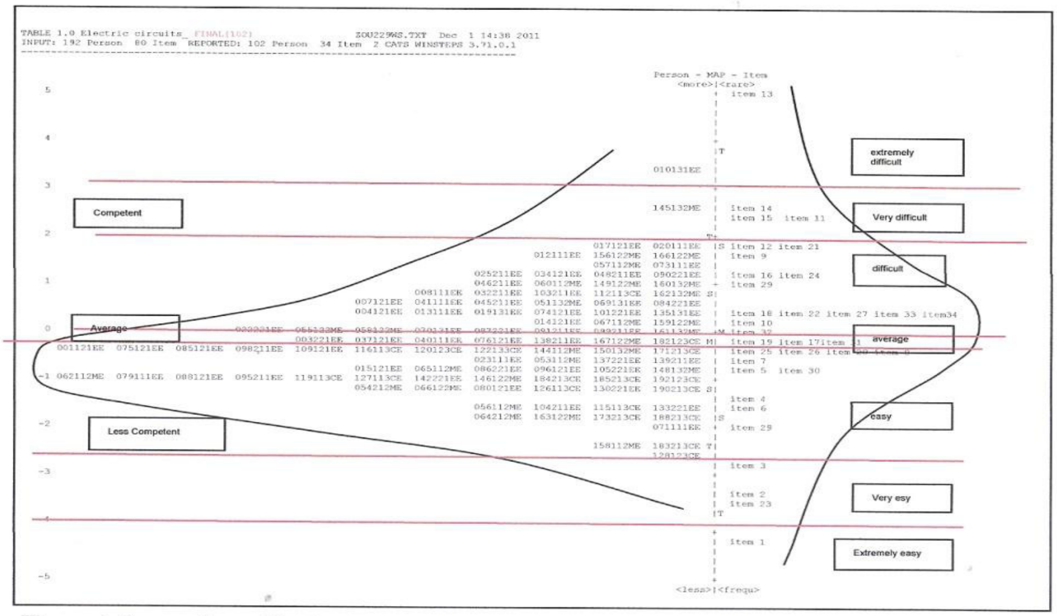


Fig. 1. Person Item Distribution Map

As for the average students, there are only seven of them consisting of 71% (N=5) Electrical Engineering while the rest of them are 14% (n=1) Mechanical and Civil Engineering students respectively. There are 50 students who are less competent in the area of parallel circuitry which consist of 42% (N=21) Electrical Engineering students, 26 % (N=13) Mechanical Engineering students and 32 % (N=16) Civil Engineering students.

Table 2. Percentage of students according to their ability

| Profile of students | Major | | |
|---|---|---|---|
| | Electrical Eng | Mechanical Eng | Civil Eng |
| Competent | 67 (N=30) | 31(N=14) | 2(N=1) |
| average | 71(N=5) | 14(N=1) | 14(N=1) |
| Less competent | 42(N=21) | 26(N=13) | 32(N=16) |

*6.3 Item Analysis*

The next part of the analysis is an analysis on each section of the instrument while observing the students' responses to the items; and taking into account of the items' difficulty levels and characteristics of misfit items.

*6.3.1 Analysis of Section 1: Meaning of parallel*

Items in Section 1 deal with the identification of circuit arrangements, each consisting of a basic circuit of two resistors and a battery. The result below (Table 3) shows that the item mean, $\mu_{item}$ is -1.52 logit (S.D.= 1.64) which means that all the three groups of engineering students had no trouble in carrying out the identification tasks. The most difficult item is at +1.51 logit while the easiest item is at -4.18 logit. Item separation is at 4.80 logit, which categorized the items into 5 different levels and item reliability is 0.96, considered as 'excellent' by Fisher (2007).

Overall, a comparison was conducted between the series and parallel circuits and it can be concluded that the students could identify the series circuits better than the parallel ones. The Electrical and the Mechanical Engineering students are more capable and skilful in terms of identifying the type of circuit diagrams compared to the Chemical Engineering group.

Table 3. Summary of 9 items in Section 1

| | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 70.4 | 102.0 | -1.52 | .31 | .94 | -.4 | .83 | -.5 |
| S.D. | 23.5 | .0 | 1.64 | .12 | .05 | .5 | .09 | .4 |
| Max. | 99.0 | 102.0 | 1.51 | .60 | 1.01 | .2 | 1.04 | .3 |
| Min. | 20.0 | 102.0 | -4.18 | .22 | .85 | -1.6 | .70 | -1.2 |

Real RMSE .33 True SD 1.60 Separation 4.80 Item Reliability .96
Model RMSE .33 True SD 1.60 Separation 4.80 Item Reliability .96
S.E. Of Item Mean = .58

### *6.3.2 Analysis of Section 2: Practical Knowledge of Current*

Questions in Section 2 test students' understanding and practical knowledge of the electrical current. All of the items in Section 2 are situated above the item mean, $\mu_{item}$ =+0.00 logit and fulfil the quality criteria in terms of fit statistics. It can be said that all these items are very challenging and the students were having a difficult time in solving the problems relating to the concept of electrical current. The overall item mean for the seven items in Section 2 is +2.24 logit (S.D. = 1.41) (refer to Table 4). The item reliability is at +0.87 logit which is 'good' according to Fisher (2007). The item separation is found to be at 2.64 which mean there are three levels of difficulties in Section 2, consisting of difficult, very difficult and extremely difficult items.

Table 4. Summary Statistics for the Items in Section 2

| | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 16.4 | 102.0 | 2.24 | .41 | 1.08 | .6 | .97 | .3 |
| S.D. | 12.9 | 0 .0 | 1.41 | .26 | .12 | .6 | .42 | 1.0 |
| Max. | 43.0 | 102.0 | 5.06 | 1.02 | 1.26 | 1.6 | 1.60 | 2.1 |
| Min. | 1.0 | 102.0 | .17 | .22 | .91 | -.2 | .42 | -.8 |

Real RMSE .5 True SD 1.32 Separation 2.64 Item Reliability .87
Model RMSE .48 True SD 1.32 Separation 2.74 Item Reliability .88
S.E. Of Item Mean = .58

Overall, the items in Section 2 are very challenging to these students. They experienced difficulties in determining the current flow in a circuit whenever there are changes made to the circuit, either when a parallel resistor is removed or when a similar battery is added to the existing one. Further analysis showed that the Electrical Engineering students is the most capable in providing the correct responses to the items in Section 2 while the Civil Engineering students are those with the lowest percentage.

### *6.3.3 Analysis of Section 3: Practical Knowledge of Voltage*

Items in Section 3 are meant to test students' practical knowledge of potential difference in a circuit containing parallel resistors. Table 5 displays the overall summary statistics for Section 3. It shows that the item mean for this section is $\mu$= +0.56 logit (S.D. = 0.67) where all 6 items are located above the overall item mean $\mu_{item}$ = +0.00 logit (see Figure1). This is an indication that the tasks given to the students in this section are rather exigent. The item reliability is at +0.87 logit and the items can be separated into 2.55 (or 2) levels of difficulty. It can be concluded that the items in Section 3 are quite challenging for the students with items ranging from -0.17

logit to +1.74 logit. The outcome also reveals that the students' conceptual understanding of the electrical voltage is quite limited in general and they need more proper training in this area.

Table 5. Summary Statistics for Section 3

| | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 36.5 | 102.0 | .56 | .24 | 1.00 | .0 | .98 | -.1 |
| S.D. | 11.6 | .0 | .67 | .02 | .07 | .7 | .11 | .7 |
| Max. | 50.0 | 102.0 | 1.74 | .29 | 1.11 | 1.1 | 1.15 | 1.1 |
| Min. | 17.0 | 102.0 | -.17 | .22 | .90 | -1.1 | .84 | -1.3 |
| Real RMSE .24 | | True SD .62 | | Separation 2.55 | Item Reliability .87 | | | |
| Model RMSE .24 | | True SD .62 | | Separation 2.59 | Item Reliability .87 | | | |
| S.E. Of Item Mean = .30 | | | | | | | | |

Overall, the students are fairly less capable of handling voltage related tasks, with the Electrical Engineering students performing better than the rest of them. Majority are still ignorant about the insignificant effect of doubling the batteries onto the voltmeters' readings across the parallel resistors. Similarly, these students have trouble in predicting the change of potential difference across the resistors when one of them is removed.

### *6.3.4 Analysis of Section 4: Practical Knowledge of Resistance*

In Section 4, the students' understanding was assessed on the concept of electrical resistance. The mean for this Section 4 is $\mu$= -0.55 logit (S.D. = 1.65), signifying an easy mission for the students (Table 6). By referring to Figure 1, there are two items which are situated above the $\mu_{item =}$ +0.00 logit line, being as 'difficult' items while the other three are below that line. The most difficult item is at +1.23 logit, while the easiest item is at -3.62 logit. Item reliability is 'excellent' according to Fisher (2007) at 0.96. The spread of the item is about +5.0 logit.

Table 6. Summary Statistics for Section 4

| | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 53.6 | 102.0 | -.55 | .28 | 1.17 | 1.8 | 1.30 | 2.0 |
| S.D. | 24.5 | .0 | 1.65 | .10 | .17 | 1.3 | .42 | 1.8 |
| Max. | 97.0 | 102.0 | 1.23 | .47 | 1.35 | 3.8 | 1.83 | 5.0 |
| Min. | 24.0 | 102.0 | -3.62 | .22 | .88 | -.2 | .60 | -.5 |
| Real RMSE .31 | | True SD 1.62 | | Separation 5.18 | Item Reliability .96 | | | |
| Model RMSE .30 | | True SD 1.62 | | Separation 5.50 | Item Reliability .97 | | | |
| S.E. Of Item Mean = .83 | | | | | | | | |

Overall, it can be concluded that the items in Section 4 are relatively easy for the students. The Mechanical Engineering students have better understanding on the overall concept of resistance with a higher percentage of 58% compared to the Electrical Engineering students (with 55%).

### *6.3.5 Analysis of Section 5: Practical Knowledge of Circuit Connection*

Section 5 is designed to test students' practical knowledge of circuit connection involving resistors. Table 7 presents the overall statistics for all items in Section 5. All three items abide to all the quality requirement of Rasch analysis. The mean is -1.05 logit suggesting that these items were non- problematic to the students participating in this research. Item separation is 2.64, placing the three items as average, easy and very easy items. The item reliability is 'good' at +0.87 logit (Fisher, 2007).

An analysis was done to compare the performance of each group. It was found that the Mechanical Engineering students are better at circuit connections compared to the other two groups of students. The series circuits are easier tasks to the students rather than the parallel ones. In general, it can be said that the items in Section 5 were unproblematic and reasonably easy for the students.

Table 7. Summary statistic of Section 5

| | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 66.7 | 102.0 | -1.05 | .24 | 1.02 | .3 | .96 | .0 |
| S.D. | 12.1 | .0 | .69 | .02 | .02 | .2 | .09 | .4 |
| Max. | 83.0 | 102.0 | -.36 | .27 | 1.04 | .5 | 1.06 | .5 |
| Min. | 54.0 | 102.0 | -1.99 | .22 | .99 | .0 | .84 | -.4 |
| Real Rmse .24 | True Sd .64 | | Separation 2.64 | | Item Reliability .87 | | | |
| Model Rmse .24 | True Sd .64 | | Separation 2.67 | | Item Reliability .88 | | | |
| S.E. Of Item Mean = .48 | | | | | | | | |

*6.3.6 Analysis of Section 6: Problem solving via Mental Model*

Section 6 is designed to examine students' problem solving skills in basic parallel resistor circuits. It is also meant to investigate whether the students are model thinkers by looking at the type of mental models used (Vosniadou, 2002) by them in their problem solving activities. The students' responses were analyzed based on the correct answer and the methodology. The mean for this section is +0.14 logit, which implies that the items are relatively easy. According to the statistics given in Table 8, the item separation is 0.67 logit, having only one difficulty level. It means that the instrument were unable to categorize the available items into categories. Hence, the item reliability is also low. The items at the maximum measure and minimum measure do not differ very much in terms of logit. The one with maximum measure is at +0.48 logit while the minimum order item is at -0.17 logit. There is a need to include other tasks to this section in order to get a variance in the difficulty level. However, with the four tasks given, it was observed that the students were able to solve those presented in the conventional manner rather than the non-conventional ones.

Table 8. Summary Statistics for Section 6

| | Total Score | Count | Measure | Model Error | Infit Mnsq | Infit Zstd | Outfit Mnsq | Outfit Zstd |
|---|---|---|---|---|---|---|---|---|
| Mean | 43.8 | 102.0 | .14 | .22 | .79 | -2.5 | .71 | -2.3 |
| S.D. | 5.4 | .0 | .27 | .00 | .03 | .3 | .04 | .2 |
| Max. | 50.0 | 102.0 | .48 | .23 | .83 | -2.0 | .77 | -2.0 |
| Min. | 37.0 | 102.0 | -.17 | .22 | .75 | -2.8 | .66 | -2.6 |
| Real RMSE .22 | True SD .15 | | Separation .67 | | Item Reliability .31 | | | |
| Model RMSE .22 | True SD .15 | | Separation .67 | | Item Reliability .31 | | | |
| S.E. Of Item Mean = .16 | | | | | | | | |

In terms of being good 'model thinkers', the Electrical Engineering students are the most competent in solving tasks in Section 6.

## 7. Conclusion

The overall analysis of results indicated that the instrument (PCCUT) is reliable and valid with the students' distribution, well matched with the items which measured the students' conceptual understanding of parallel resistors. It is then, recommended that the PCCUT to be used as one of the tools in measuring the students' basic knowledge, particularly in parallel resistors before they embarked on an introductory course in electricity. The information obtained from the results is capable in identifying the problematic areas in which the students were having difficulties in. Identifying these difficulties allows proper planning of strategies of the instructional methods to be carried out within the learning environment.

The results from the analysis enabled the items in PCCUT to be placed in a hierarchical order. This is an indication that there is a possibility of profiling the students according to their basic conceptual understanding of electricity. In addition, the work reported in this research has been limited to particular cohorts of engineering students. However, the research could be applied more widely by including the engineering students studying basic electricity in other local universities.

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